

On Problems and Solutions of General Relativity (Commemoration of the 100th Anniversary of General Relativity)

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In commemoration of the 100th anniversary of general relativity, many others would look back on its history and achievements, so I will write mine focusing on the problems of general relativity and their solutions.

Pieces of writing hereunder are the rearrangement of my past idea from thesis [1] [2] and postings on my personal blog [3] and science community by focusing on the theme of problems and solutions of general relativity.

I. Several problems of general relativity

Since its publication [4], general theory of relativity has been numerously challenged but time-tested in the process through numerous experiments (Gravitational time dilation and frequency shift, Precession of apses, Gravitational lensing...). [5] [6]

However, the possibility and demand for revised general relativity is also coming to the fore. This arises from its own problem of general relativity or is required from newly found observations. In my eyes, currently, there are three big problems with respect to general relativity.

1) Problems of integration with quantum mechanics and the case of a very big curvature in space-time [5] [7]

2) The theory includes the existence of singularity, which denies the application of general relativity itself, as a solution for field equation. [5]

3) Rising of the problems of dark energy and dark matter [8–13]

I would investigate these problems in reverse order and propose my ideas to work them out or solutions.

II. Problems of dark energy and dark matter

1. Rising of the problems of dark energy and dark matter

To explain the phenomena currently observed from the universe, we assume the need for something unknown called dark matter and dark energy. [8] [9] However, since its quantity is so great (95% level of total mass in the universe) [14] [15] but not detected from our surroundings, [16–18] opinions are coming forth that general relativity should be revised into other forms as to the outside of the solar system.

While the standard model makes up a whole system with its entirety tested through experiments, dark matter is expected not to belong to this standard model. [19] One of the ways to solve this problem is a revision of general relativity.

Accelerated expansion of the universe suggests the existence of new force similar to anti-gravity, which is a result different from the initial expectation of general relativity. [6]

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Demetrios Christodoulou



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Problem Book in Relativity and Gravitation Alan P Lightman, William H. Press, Richard H. Price, Saul A.

Teukolsky, 2017-09-01 An essential resource for learning about general relativity and much more from four leading experts Important and useful to every student of relativity this book is a unique collection of some 475 problems with solutions in the fields of special and general relativity gravitation relativistic astrophysics and cosmology The problems are expressed in broad physical terms to enhance their pertinence to readers with diverse backgrounds In their solutions the authors have attempted to convey a mode of approach to these kinds of problems revealing procedures that can reduce the labor of calculations while avoiding the pitfall of too much or too powerful formalism Although well suited for individual use the volume may also be used with one of the modern textbooks in general relativity

Introduction To General Relativity: Solutions To Problems John Dirk Walecka, 2017-06-16 It is important for every physicist today to have a working knowledge of Einstein's theory of general relativity Introduction to General Relativity published in 2007 was aimed at first year graduate students or advanced undergraduates in physics Only a basic understanding of classical lagrangian mechanics is assumed beyond that the reader should find the material to be self contained The mechanics problem of a point mass constrained to move without friction on a two dimensional surface of arbitrary shape serves as a paradigm for the development of the mathematics and physics of general relativity Special relativity is reviewed The basic principles of general relativity are then presented and the most important applications are discussed The final special topics section takes the reader up to a few areas of current research An extensive set of accessible problems enhances and extends the coverage As a learning and teaching tool this current book provides solutions to those problems This text and solutions manual are meant to provide an introduction to the subject It is hoped that these books will allow the reader to approach the more advanced texts and monographs as well as the continual influx of fascinating new experimental results with a deeper understanding and sense of appreciation

Special Relativity Michael Tsamparlis, 2010-05-17 Writing a new book on the classic subject of Special Relativity on which numerous important physicists have contributed and many books have already been written can be like adding another epicycle to the Ptolemaic cosmology Furthermore it is our belief that if a book has no new elements but simply repeats what is written in the existing literature perhaps with a different style then this is not enough to justify its publication However after having spent a number of years both in class and research with relativity I have come to the conclusion that there exists a place for a new book Since it appears that somewhere along the way mathematics may have obscured and prevailed to the degree that we tend to teach relativity and I believe theoretical physics simply using heavier mathematics without the inspiration and the mastery of the classic physicists of the last century Moreover current trends encourage the application of techniques in producing quick results and not tedious conceptual approaches resulting in long lasting reasoning On the other hand physics cannot be done a la carte stripped from philosophy or to put it in a simple but

dramatic context A building is not an accumulation of stones As a result of the above a major aim in the writing of this book has been the distinction between the mathematics of Minkowski space and the physics of activity

Problems in the General Theory of Relativity and Theory of Group Representations N. G. Basov, 2012-12-06 This collection contains survey articles dealing with the following topics The Mach principle and its role in the general theory of relativity the modern conception of the vacuum new methods in the theory of Lie group representations the coherent state method and its application to physical problems and the Newman Penrose method and its application to problems in general relativity theory

A Short Course in General Relativity James A. Foster, J. David Nightingale, 2010-04-30 Suitable for a one semester course in general relativity for senior undergraduates or beginning graduate students this text clarifies the mathematical aspects of Einstein's theory of relativity without sacrificing physical understanding The text begins with an exposition of those aspects of tensor calculus and differential geometry needed for a proper treatment of the subject The discussion then turns to the spacetime of general relativity and to geodesic motion A brief consideration of the field equations is followed by a discussion of physics in the vicinity of massive objects including an elementary treatment of black holes and rotating objects The main text concludes with introductory chapters on gravitational radiation and cosmology This new third edition has been updated to take account of fresh observational evidence and experiments It includes new sections on the Kerr solution in Chapter 4 and cosmological speeds of recession in Chapter 6 A more mathematical treatment of tensors and manifolds included in the 1st edition but omitted in the 2nd edition has been restored in an appendix Also included are two additional appendixes Special Relativity Review and The Chinese Connection and outline solutions to all exercises and problems making it especially suitable for private study

300 Problems in Special and General Relativity Mattias Blennow, Tommy Ohlsson, 2021-12-09 Einstein's theories of special relativity and general relativity form a core part of today's undergraduate or Masters level physics curriculum This is a supplementary problem book or student's manual consisting of 150 problems in each of special and general relativity The problems which have been developed tested and refined by the authors over the past two decades are a mixture of short form and multi part extended problems with hints provided where appropriate Complete solutions are elaborated for every problem in a different section of the book some solutions include brief discussions on their physical or historical significance Designed as a companion text to complement a main relativity textbook it does not assume access to any specific textbook This is a helpful resource for advanced students for self study a source of problems for university teaching assistants or as inspiration for instructors and examiners constructing problems for their lectures homework or exams

A Student's Manual for A First Course in General Relativity Robert B. Scott, 2016 This comprehensive student manual has been designed to accompany the leading textbook by Bernard Schutz A First Course in General Relativity and uses detailed solutions cross referenced to several introductory and more advanced textbooks to enable self learners undergraduates and postgraduates to master general relativity through problem solving The perfect

accompaniment to Schutz's textbook this manual guides the reader step by step through over 200 exercises with clear easy to follow derivations. It provides detailed solutions to almost half of Schutz's exercises and includes 125 brand new supplementary problems that address the subtle points of each chapter. It includes a comprehensive index and collects useful mathematical results such as transformation matrices and Christoffel symbols for commonly studied spacetimes in an appendix. Supported by an online table categorising exercises, a Maple worksheet and an instructors manual, this text provides an invaluable resource for all students and instructors using Schutz's textbook.

Mathematical Problems of General Relativity I Demetrios Christodoulou, 2008. General relativity is a theory proposed by Einstein in 1915 as a unified theory of space time and gravitation. It is based on and extends Newton's theory of gravitation as well as Newton's equations of motion. It is thus fundamentally rooted in classical mechanics. The theory can be seen as a development of Riemannian geometry itself, an extension of Gauss' intrinsic theory of curved surfaces in Euclidean space. The domain of application of the theory is astronomical systems. One of the mathematical methods analyzed and exploited in the present volume is an extension of Noether's fundamental principle connecting symmetries to conserved quantities. This is involved at a most elementary level in the very definition of the notion of hyperbolicity for an Euler-Lagrange system of partial differential equations. Another method, the study and systematic use of foliations by characteristic null hypersurfaces, is in the spirit of Roger Penrose's approach in his incompleteness theorem. The methods have applications beyond general relativity to problems in fluid mechanics and more generally to the mechanics and electrodynamics of continuous media. The book is intended for advanced students and researchers seeking an introduction to the methods and applications of general relativity.

Pseudo-Complex General Relativity Peter O. Hess, Mirko Schäfer, Walter Greiner, 2015-10-31. This book explores the role of singularities in general relativity (GR). The theory predicts that when a sufficiently large mass collapses, no known force is able to stop it until all mass is concentrated at a point. The question arises whether an acceptable physical theory should have a singularity, not even a coordinate singularity. The appearance of a singularity shows the limitations of the theory. In GR, this limitation is the strong gravitational force acting near and at a super-massive concentration of a central mass. First, a historical overview is given on former attempts to extend GR, which includes Einstein himself, all with distinct motivations. It will be shown that the only possible algebraic extension is to introduce pseudo-complex (pc) coordinates; otherwise, for weak gravitational fields, non-physical ghost solutions appear. Thus, the need to use pc variables. We will see that the theory contains a minimal length with important consequences. After that, the pc GR is formulated and compared to the former attempts. A new variational principle is introduced, which requires in the Einstein equations an additional contribution. Alternatively, the standard variational principle can be applied, but one has to introduce a constraint with the same former results. The additional contribution will be associated to vacuum fluctuation, whose dependence on the radial distance can be approximately obtained using semi-classical Quantum Mechanics. The main point is that pc GR predicts that mass not only

curves the space but also changes the vacuum structure of the space itself In the following chapters the minimal length will be set to zero due to its smallness Nevertheless the pc GR will keep a remnant of the pc description namely that the appearance of a term which we may call dark energy is inevitable The first application will be discussed in chapter 3 namely solutions of central mass distributions For a non rotating massive object it is the pc Schwarzschild solution for a rotating massive object the pc Kerr solution and for a charged massive object it will be the Reissner Nordström solution This chapter serves to become familiar on how to resolve problems in pc GR and on how to interpret the results One of the main consequences is that we can eliminate the event horizon and thus there will be no black holes The huge massive objects in the center of nearly any galaxy and the so called galactic black holes are within pc GR still there but with the absence of an event horizon Chapter 4 gives another application of the theory namely the Robertson Walker solution which we use to model different outcomes of the evolution of the universe Finally the capability of this theory to predict new phenomena is illustrated

Solutions of Some Selected Problems in General Relativity Ming-Yang Wang, 1974 **A Mathematical Journey to Relativity** Wladimir-Georges Boskoff, Salvatore Capozziello, 2020-06-01 This book opens with an axiomatic description of Euclidean and non Euclidean geometries Euclidean geometry is the starting point to understand all other geometries and it is the cornerstone for our basic intuition of vector spaces The generalization to non Euclidean geometry is the following step to develop the language of Special and General Relativity These theories are discussed starting from a full geometric point of view Differential geometry is presented in the simplest way and it is applied to describe the physical world The final result of this construction is deriving the Einstein field equations for gravitation and spacetime dynamics Possible solutions and their physical implications are also discussed the Schwarzschild metric the relativistic trajectory of planets the deflection of light the black holes the cosmological solutions like de Sitter Friedmann Lemaître Robertson Walker and Gödel ones Some current problems like dark energy are also sketched The book is self contained and includes details of all proofs It provides solutions or tips to solve problems and exercises It is designed for undergraduate students and for all readers who want a first geometric approach to Special and General Relativity *The General Theory of Relativity* Anadijiban Das, Andrew DeBenedictis, 2012-06-26 The General Theory of Relativity A Mathematical Exposition will serve readers as a modern mathematical introduction to the general theory of relativity Throughout the book examples worked out problems and exercises with hints and solutions are furnished Topics in this book include but are not limited to tensor analysis the special theory of relativity the general theory of relativity and Einstein's field equations spherically symmetric solutions and experimental confirmations static and stationary space time domains black holes cosmological models algebraic classifications and the Newman Penrose equations the coupled Einstein Maxwell Klein Gordon equations appendices covering mathematical supplements and special topics Mathematical rigor yet very clear presentation of the topics make this book a unique text for both university students and research scholars Anadijiban Das has taught courses on Relativity Theory

at The University College of Dublin Ireland Jadavpur University India Carnegie Mellon University USA and Simon Fraser University Canada His major areas of research include among diverse topics the mathematical aspects of general relativity theory Andrew DeBenedictis has taught courses in Theoretical Physics at Simon Fraser University Canada and is also a member of The Pacific Institute for the Mathematical Sciences His research interests include quantum gravity classical gravity and semi classical gravity

General Relativity Nicola Vittorio, 2025-07-09 This book provides General Relativity problems to be tackled both analytically and symbolically numerically with the Mathematica software In the first case the reader is guided in setting up the appropriate solutions In the second case the reader is provided with very illustrative notebooks to carry out the steps necessary to solve a General Relativity problem These include the calculation of the Christoffel symbols Riemann Ricci Einstein and energy momentum tensors as well as the resolution of the field equations of General Relativity in different astrophysical cosmological contexts with and without the introduction of a cosmological constant This study guide should be used alongside existing textbooks to provide additional learning and engagement opportunities for advanced undergraduate and graduate students in physics and astrophysics taking courses on general relativity It may also be of interest to mathematics students interested in celestial mechanics and space sciences A number of the Mathematica codes used in this book can be accessed online here [INSERT URL WHEN AVAILABLE](#) Key Features Promotes the learning by doing approach guiding the student in the building of the mathematical apparatus necessary to solve problems in General Relativity Encourages the development of analytical skills to address and solve specific and challenging problems in General Relativity Develops symbolic numerical skills to address problems often already solved analytically so that the reader is prepared to attack even more elaborate calculations in General Relativity

Introduction to General Relativity and the Cosmological Constant Problem Marcelo Samuel Berman, 2007 This book is an introductory text in General Relativity while also focusing some solutions to the cosmological constant problem which consists in an amazing 100 orders of magnitude discrepancy between the value of this constant in the present Universe and its estimated value in the very early epoch The author suggests that the constant is in fact a time varying function of the age of the Universe The book offers a wealth of cosmological models treats up to date findings like the verification of the Lense Thirring effect in the year 2004 and the recently published research by Cooperstock and Tieu 2005 suggesting that dark matter is not a necessary concept in order to explain the rotational velocities of stars around galaxies nuclei This is a mathematical cosmology textbook that may lead undergraduates and graduate students to one of the frontiers of research while keeping the prerequisites to a minimum because most of the theory in the book requires only prior knowledge of Calculus and a University Physics course

A Short Course in General Relativity J. Foster, 2006 Suitable for a one semester course in general relativity for senior undergraduates or beginning graduate students this text clarifies the mathematical aspects of Einstein's theory of relativity without sacrificing physical understanding The text begins with an

exposition of those aspects of tensor calculus and differential geometry needed for a proper treatment of the subject. The discussion then turns to the spacetime of general relativity and to geodesic motion. A brief consideration of the field equations is followed by a discussion of physics in the vicinity of massive objects including an elementary treatment of black holes and rotating objects. The main text concludes with introductory chapters on gravitational radiation and cosmology. This new third edition has been updated to take account of fresh observational evidence and experiments. It includes new sections on the Kerr solution in Chapter 4 and cosmological speeds of recession in Chapter 6. A more mathematical treatment of tensors and manifolds included in the 1st edition but omitted in the 2nd edition has been restored in an appendix. Also included are two additional appendixes: Special Relativity Review and The Chinese Connection. And outline solutions to all exercises and problems making it especially suitable for private study.

The Cauchy Problem in General Relativity Hans Ringström, 2009. The general theory of relativity is a theory of manifolds equipped with Lorentz metrics and fields which describe the matter content. Einstein's equations equate the Einstein tensor, a curvature quantity associated with the Lorentz metric, with the stress energy tensor, an object constructed using the matter fields. In addition, there are equations describing the evolution of the matter. Using symmetry as a guiding principle, one is naturally led to the Schwarzschild and Friedmann-Lemaître-Robertson-Walker solutions, modelling an isolated system and the entire universe respectively. In a different approach, formulating Einstein's equations as an initial value problem allows a closer study of their solutions. This book first provides a definition of the concept of initial data and a proof of the correspondence between initial data and development. It turns out that some initial data allow non-isometric maximal developments, complicating the uniqueness issue. The second half of the book is concerned with this and related problems, such as strong cosmic censorship. The book presents complete proofs of several classical results that play a central role in mathematical relativity but are not easily accessible to those without prior background in the subject. Prerequisites are a good knowledge of basic measure and integration theory as well as the fundamentals of Lorentz geometry. The necessary background from the theory of partial differential equations and Lorentz geometry is included.

Lectures on General Relativity A. Papapetrou, 2012-12-06. This book is an elaboration of lecture notes for the graduate course on General Relativity given by the author at Boston University in the spring semester of 1972. It is an introduction to the subject only, as the time available for the course was limited. The author of an introduction to General Relativity is faced from the beginning with the difficult task of choosing which material to include. A general criterion assisting in this choice is provided by the didactic character of the book. Those chapters have to be included in priority which will be most useful to the reader in enabling him to understand the methods used in General Relativity, the results obtained so far, and possibly the problems still to be solved. This criterion is not sufficient to ensure a unique choice. General Relativity has developed to such a degree that it is impossible to include in an introductory textbook of a reasonable length, even a very condensed treatment of all important problems which have been discussed until now, and the author is obliged to decide in a

more or less subjective manner which of the more recent developments to omit The following lines indicate by means of some examples the kind of choice made in this book

The N-Body Problem in General Relativity T. Levi-Civita, 1964 1 IN THE MONOGRAPH SERIES directed by Henri Villat several fasci cules have been devoted to Relativity First there are the general presentations of Th De Donder nos 8 14 43 58 and then those more specifically devoted to Einsteinian gravitation notably Georges Darmais contribution no 25 and that of J Haag no 46 on the Schwarzschild problem The present fascicule takes its place alongside the two latter monographs but it has been conceived and composed in such a way that it may be read and understood by anyone with a knowledge of the principles of Absolute Differential Calculus and of Relativity either from the original expositi ons of Einstein Weyl or Eddington or in French from Cartan s excel 2 lent works for everything having to do with mathematical theories and 3 from Chazy s for Relativity and Celestial Mechanics or naturally from Levi Civita s The Absolute Differential Calculus first edition London and Glasgow Blackie and Son 1927 where the two original papers written in Italian are brought together namely Calcolo differenziale assoluto and Fondamenti di meccanica relativistica Bologna Zanichelli As for the present fascicule it is hardly necessary to point out that as its title indicates we seek to establish in the simplest possible terms the rela tivistic aspect of what Newton and those who followed him regarded as the key to ordinary Celestial Mechanics

Introduction to General Relativity John Dirk Walecka, 2007

General Relativity Malcolm Ludvigsen, 1999-05-28 Starting with the idea of an event and finishing with a description of the standard big bang model of the Universe this textbook provides a clear concise and up to date introduction to the theory of general relativity suitable for final year undergraduate mathematics or physics students Throughout the emphasis is on the geometric structure of spacetime rather than the traditional coordinate dependent approach This allows the theory to be pared down and presented in its simplest and most elegant form Topics covered include flat spacetime special relativity Maxwell fields the energy momentum tensor spacetime curvature and gravity Schwarzschild and Kerr spacetimes black holes and singularities and cosmology In developing the theory all physical assumptions are clearly spelled out and the necessary mathematics is developed along with the physics Exercises are provided at the end of each chapter and key ideas in the text are illustrated with worked examples Solutions and hints to selected problems are also provided at the end of the book This textbook will enable the student to develop a sound understanding of the theory of general relativity and all the necessary mathematical machinery

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